2118
doi:10.1017/S1431927618011078

Microsc. Microanal. 24 (Suppl 1), 2018


# Coordinated Analyses of the Chemical and Microstructural Effects of Progressive Space Weathering of a Carbonaceous Chondrite

Michelle S. Thompson[1], Mark J. Loeffler[2], Richard V. Morris[1], Simon J. Clemett[3], Roy Christoffersen[3], Zia Rahman[3], David G. Agresti[4] and Lindsay P. Keller[1]

[1.] ARES, NASA Johnson Space Center, Houston, TX.
[2.] Northern Arizona University, Department of Physics and Astronomy, Flagstaff, AZ.
[3.] Jacobs, NASA Johnson Space Center, Houston, TX.
[4.] University of Alabama at Birmingham, Department of Physics, Birmingham, AL.

Mineral grains on the surfaces of airless bodies are continually modified by micrometeorite impacts and exposure to energetic particles from the solar wind. These processes, collectively known as space weathering, alter the microstructure, chemical composition, and optical properties of surface grains [1]. Understanding the effects of space weathering is critical for interpreting spectroscopic data from remote sensing spacecraft and for analyzing returned samples from past and future missions to airless body surfaces.

Microstructural and chemical characteristics attributed to space weathering processes have been identified in returned samples from the surface of the Moon and near-Earth asteroid Itokawa. Such features manifest at the micro- and nano-scales and include amorphous grain rims, vesicles, chemically-distinct surface-correlated deposits, and nanophase Fe particles (npFe) e.g., [2]. While the community has made significant progress towards understanding the space weathering of lunar and ordinary chondritic materials, space weathering of the organic-rich, primitive materials in carbonaceous chondrites is not well-constrained. In advance of sample return from ongoing missions to such bodies, e.g., Hayabusa2 and OSIRIS-REx, we can understand the effect of space weathering on these materials by simulating these processes in the laboratory. Pulsed-laser irradiation simulates the short-duration energy transfer associated with micrometeorite impacts, creating products in experimental samples that effectively replicate the spectral properties, and some of the microstructural and chemical characteristics of returned samples, e.g., [3]. Here we present nanoscale analyses of the effects of simulated micrometeorite impacts on both organic and inorganic components of carbonaceous chondrites.

We performed our laser irradiation experiments using the CM2 Murchison meteorite, which has been identified as being an appropriate spectral analog for the bodies targeted by the ongoing OSIRIS-REx and Hayabusa2 missions. In order to simulate micrometeorite impacts, we subjected three individual chips of dry-cut Murchison to pulsed laser irradiation, rastering the laser over a 0.5 cm square region on the surface of the sample 1, 2, and 5 times (1x, 2x, and 5x). We measured the reflectance spectra (0.35-2.5 μm) of the chips relative to a 99% Spectralon standard with an ASD Field-Spec 3 spectrometer. We performed organic functional group chemical analyses for both laser irradiated and unirradiated surfaces using the $\mu L^2MS$ instrument at NASA Johnson Space Center (JSC). We used the FEI Quanta 3D focused ion beam scanning electron microscope (FIB-SEM) at JSC to investigate the surface morphological changes that occurred as a result of progressive irradiation, and to prepare electron transparent thin sections for analyses in the transmission electron microscope (TEM). We used the JEOL 2500SE scanning TEM at JSC equipped with bright-field (BF) and dark-field (DF) detectors and a Thermo thin-window energy-dispersive X-ray spectrometer (EDS) to determine the chemical and microstructural changes that occurred as a result of the simulated micrometeorite impact events.

Reflectance spectra in the VIS-NIR wavelength range show an overall brightening and a weakening of the 0.7 μm band (associated with $Fe^{2+}$ to $Fe^{3+}$ charge transfer in phyllosilicates) with increasing laser exposure. These results indicate that phyllosilicate phases are modified with continued laser irradiation and suggest that the irradiation may be creating nanophase particles which are contributing to the increase in brightness in the surface. Spectral maps of organics at the boundary of the 1x lasered and raw meteorite surface, obtained with the $\mu L^2MS$ instrument, show an increased abundance of simple free organic species in the irradiated material compared to the unaltered region (Fig. 1). Our results suggest that laser irradiation is acting to depolymerize and break down the abundant macromolecular material in Murchison, indicating that space weathering may play an important role in the alteration of organic species on airless body surfaces. FIB-SEM observations of the surface of the meteorite show vesiculated and melted features consistent with the outgassing of volatiles (e.g., burst vesicles). Subsequent analyses of a TEM section prepared from the 1 x lasered sample matrix revealed the presence of microstructurally and chemically complex deposits on the meteorite surface. Several features were also consistent with melting processes, including the presence of melt droplets, vesicles, and abundant nanoparticles (Fig. 2). EDS maps of the melt deposits show they are composed of Fe, S, Si, and O, and that embedded nanoparticles range in size from 3-30 nm. Compositionally, the majority of nanoparticles are Fe-Ni-S grains, indicating that sulfide phases play a critical role in the space weathering of carbonaceous materials (Fig. 2).

References:

[1] B Hapke, Journal of Geophysical Research-Planets **106** (2001), p. 10,039.
[2] L P Keller and D. S. McKay, Geochimica et Cosmochimica Acta **61** (1997) p. 2331.
[3] S Sasaki *et al,* Nature **410** (2001), p. 555.

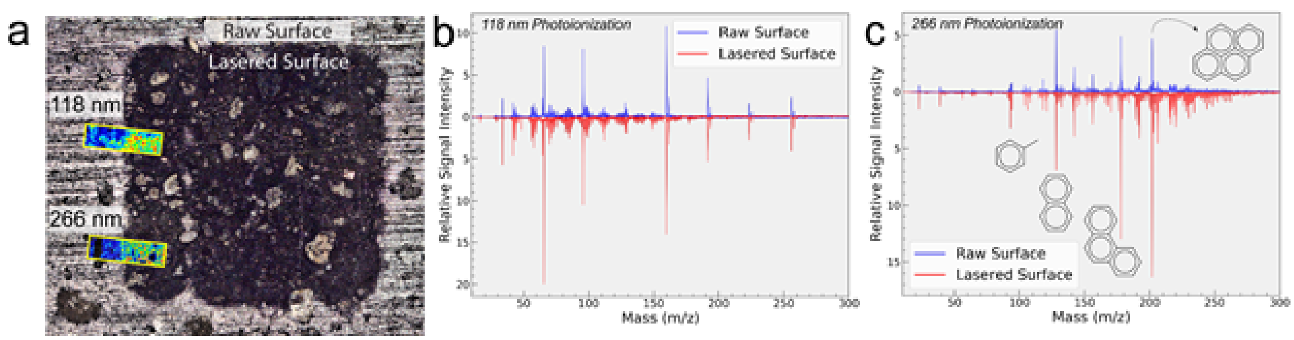


**Figure 1.** $\mu L^2MS$ data showing a) maps of organic detection at both 118nm and 266 nm wavelengths, and signal intensities observed for b) 118 nm wavelengths and c) 266 nm wavelengths, raw surface (blue) and irradiated (red).

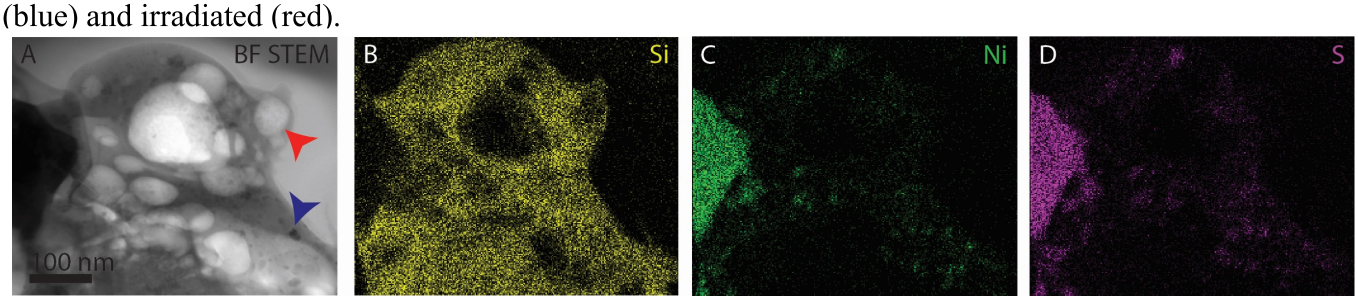


**Figure 2.** a) BF STEM image of a melt droplet with red arrow indicating vesicles, and purple arrows indicating nanoparticles. EDS maps showing b) Si, c) Ni, and d) S.

https://doi.org/10.1017/S1431927618011078 Published online by Cambridge University Press